Field	Study Information
Title	Modeling Carbon Dioxide Leakage and Potential Environmental Impacts from Carbon Sequestration Projects on the Outer Continental Shelf (OCS)
Administered by	Office of Environmental Programs
BOEM Contact(s)	Melissa Batum (melissa.batum@boem.gov), Zhen Li (zhen.li@boem.gov))
Procurement Type(s)	Contract
Conducting Organization(s)	TBD
Total BOEM Cost	TBD
Performance Period	FY 2025–2027
Final Report Due	TBD
Date Revised	April 23, 2024
Problem	Potential CO_2 leakage from carbon sequestration (CS) project activities could occur via a number of pathways. Few studies model and/or measure CO_2 leakage, transport, dispersion, attenuation, and environmental impacts in the offshore environment, and those that do exist are preliminary.
Intervention	BOEM needs more information about the dynamics, fate, transport, and potential environmental impacts of CO_2 leakage under various scenarios, including worst-case, on the OCS to inform the new nationwide CS Program and to protect the environment from CO_2 leakage.
Comparison	The study will model CO_2 leakage under various scenarios, including worst-case scenarios, using the GOM OCS Region as a case-study and can be applied to all OCS regions.
Outcome	The leakage and worst-case scenario modeling will aid BOEM's ongoing rulemaking efforts, program development and implementation, and future operational needs including NEPA analyses, lease planning, lease stipulations, consultations, plan and permit approvals, mitigation measures, risk assessment and monitoring requirements, etc. Study results will also provide direction for future studies to include field and/or laboratory analyses.
Context	This study will be applicable to all OCS Regions, with a case-study focused on the Gulf of Mexico (GOM).

BOEM Information Need(s): BOEM needs to understand of the impacts of CO_2 leakage on the coastal, marine, and human environment to evaluate potential impacts from CS activities on the Outer Continental Shelf (OCS). BOEM needs background and modeling information about the dynamics, fate, transport, and potential environmental impacts of CO_2 leakage under various scenarios. The information will inform leasing scenarios and decisions, NEPA analyses, mitigation measures, and risk assessment and monitoring requirements for CS projects and protect the environment from CO_2 leakage.

Background: Atmospheric levels of GHGs are reaching a point where a global reduction of GHG emissions is not enough to curtail the worse effects of climate change; a rapid reduction of GHG emissions to net-zero human emissions is now necessary to prevent the more catastrophic impacts of climate change from striking communities and countries around the world. CS is an necessary part of current climate mitigation models (IPCC 2023, IPCC 2005, NAS 2019, NAS 2021, IEA 2021, US State Dept 2021) and the United States' goal to reach net-zero carbon emissions by 2050, and international goals to limit global surface warming to +2˚C or lower by 2100.

The INVEST in America Act (i.e., Bipartisan Infrastructure Law) of 2021 amended the Outer Continental Shelf Lands Act's (OCSLA's) leasing provisions to authorize the U.S. Department of Interior (DOI) to grant leases, easements, and rights-of-way on the OCS for the purpose of carbon sequestration (See 43 U.S.C. § 1337(p)(1)). BOEM and BSEE are currently developing regulations to implement a nationwide OCS CS Program, with the anticipation of a CS lease sale in the GOM after final regulations are published.

Protecting the environment is central to every aspect and phase of the implementation of CS projects on the OCS, especially protection from potential CO_2 leakage. Understanding the impacts of CO_2 leakage is paramount to informing regulatory, policy, and environmental decisions and facilitating effective environmental protection during project implementation. Preliminary studies modeling several CO_2 leakage scenarios in the GOM (e.g., Oldenburg and Pan 2020, RISCS Consortium 2014) could inform the development of a CO_2 leakage model for the OCS. The modeling results from this study will inform CO_2 leakage and worst-case scenarios for NEPA analyses, consultations, mitigations measures, conditions of approval, and other environmental issues and decisions. The study results will also inform ongoing rulemaking efforts, CS program development and implementation, and future operational lease planning, plan and permit approvals, risk assessment and monitoring requirements.

Objective(s): The objectives of this research include:

- Collect and evaluate existing data and information on "background" levels of CO_2 in the marine environment for the GOM OCS region. Information should include seasonal and other types of and mechanisms for variability in naturally occurring CO_2 levels.
- Evaluate existing CO_2 leakage models and pilot tests (small-scale field tests) that analyze the dispersion, fate, and transport of CO_2 in the ocean from various potential leakage pathways (e.g., Oldenburg and Pan 2020, RISCS Consortium 2014) and determine how they can be applied the GOM OCS region.
- Model CO_2 leakage, dispersion, fate, and transport under various scenarios, including worst-case scenarios from multiple projects for the GOM OCS Region. Scenarios, at a minimum, should include varying volumes and pressures from pipeline ruptures, injection well blowouts, and leakages via legacy wells and geologic pathways such as reactivated faults.
- Model potential chemical oceanography and environmental impacts from the various leakage scenarios.
- Recommend methods and protocols for most effectively incorporating modeling scenarios into risk assessment and monitoring requirements for CS projects.

Methods: The study will compile, review, and synthesize existing information and models for modeling CO_2 leakage scenarios from CS project activities via a number of pathways (e.g., pipeline rupture, well blowouts, and leakages via legacy wells and geologic pathways such as reactivated faults) that may be applicable for each OCS region (e.g., Oldenburg and Pan 2020, RISCS Consortium 2014). The study will identify the types of models currently being used in the offshore environment to inform the development of a national OCS CO_2 leakage model.

The study will also collect and evaluate existing data and information on "background" levels of CO_2 in the marine environment for the GOM region of the OCS. Information should include seasonal and other types of and mechanisms for variability in naturally occurring CO_2 levels. Most of the world's ocean CO_2 measurement technologies and methods are conducted by NOAA, which is responsible for measurements of surface ocean CO_2 and ocean carbon chemistry including dissolved inorganic carbon (DIC), pH, and calculated surface ocean pCO_2. EPA also contributes by publishing trends in pH and related properties of ocean water, based on a combination of direct observations, calculations, and modeling. In addition, the US Department of Energy's National Renewable Energy Laboratory and Pacific Northwest National Laboratory also study ocean CO_2 measurement and processes. NASA's ICESAT-2 mission also offers opportunities to monitor ocean carbon fluxes including as air-sea fluxes of CO_2, ocean primary production, lateral fluxes, and the inventories within these fluxes such as, ocean phytoplankton biomass, ocean alkalinity, and open ocean dissolved organic carbon.

The study will model CO_2 leakage under various scenarios, including worst-case scenarios, from multiple projects to determine CO_2 dispersion, fate, and transport for the GOM OCS region. Region specific geologic scenarios will be evaluated. The study will also model impacts to chemical oceanography and potential environmental impacts using the CO_2 background data/information and various CO_2 leakage and worst-case modeling scenarios. The study will deliver modeling methods and modeling analyses for the CO_2 leakage, dispersion, fate, transport, and potential impacts. It will deliver methods and protocols for most effectively incorporating modeling scenarios and results into leasing planning and scenarios,

NEPA analyses, consultations, leakage modeling, mitigation measures, lease stipulations, conditions of approval, risk assessment and monitoring requirements, and other environmental needs and decisions (above) for CS projects. The study will also assess the gaps in understanding CO_2 background levels, CO_2 leakage modeling, and leakage impacts, and recommend direction for future studies to include field and/or laboratory analyses.

Specific Research Question(s):

1. What are the existing models and pilot tests that analyze the dispersion, fate, and transport of CO_2 in the ocean from various potential leakage pathways (e.g., Oldenburg and Pan 2020, RISCS Consortium 2014)?
2. What are appropriate CO_2 leakage modeling scenarios for the GOM OCS Region that can be developed into a national OCS CO_2 fate and transport model? What are appropriate worst-case CO_2 leakage scenarios for the GOM OCS region?
3. What are considered "background" CO_2 levels in the GOM OCS region?
4. What are the dispersion patterns, fate, transport, and potential environmental impacts from the various CO_2 leakage scenarios? What are the most important factors affecting CO_2 leakage dispersion, fate, and transport (e.g., water depth)?
5. What are the most effective methods and protocols to incorporate the study results into risk assessment and monitoring requirements for CS project? What are the gaps in understanding background CO_2 levels, CO_2 leakage modeling, and modeling potential environmental impacts from CO_2 leakage?

Current Status: N/A

Publications Completed: N/A

Studies Development Plan FY 2025–2026 229

Affiliated WWW Sites: N/A

References:

Blackford JC, Beaubien SE, Foekema EM, Gemeni V, Gwosdz S, Jones D, Kirk K, Lions J, Metcalfe R, Moni C, et al. 2014. A guide to potential impacts of leakage from CO_2 storage. RISCS Consortium. Project No. 240837. https://edepot.wur.nl/400248

[IEA] International Energy Agency. 2021. Net zero by 2050: a roadmap for the global energy sector. Paris (FR): International Energy Agency. https://www.iea.org/reports/net-zero-by-2050.

[IPCC] Intergovernmental Panel on Climate Change. 2023. Summary for policymakers. In: Climate change 2023: synthesis report. Contribution of Working Groups I, II and III to the sixth assessment report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. Geneva (CH): IPCC. p. 1-–4, DOI: 10.59327/IPCC/AR6-9789291691647.001, https://www.ipcc.ch/report/sixth-assessment-report-cycle/

[IPCC] Intergovernmental Panel on Climate Change. 2005. Carbon dioxide capture and storage. Cambridge (UK): Cambridge University Press. 431 p. https://ipcc.ch/report/carbon-dioxide-capture-and-storage/

[NAS] National Academies of Sciences, Engineering, and Medicine. 2019. Negative emissions technologies and reliable sequestration: a research agenda. Washington (DC): The National Academies Press. https://doi.org/10.17226/25259.

Oldenburg CM, Pan L. 2020. Major CO_2 blowouts from offshore wells are strongly attenuated in water deeper than 50 m. Greenhouse Gases Sci Technol. 10(1):15–31.